

connections, allowing us to generate and weigh far more variables and agendas than before.

When this development proceeds normally, we get better at balancing impulse, desire, goals, self-interest, rules, ethics, and even altruism, generating behavior that is more complex and, sometimes at least, more sensible. But at times, and especially at first, the brain does this work clumsily. It's hard to get all those new cogs to mesh.

Beatriz Luna, a University of Pittsburgh professor of psychiatry who uses neuroimaging to study the teen brain, used a simple test that illustrates this learning curve. Luna scanned the brains of children, teens, and twentysomethings while they performed an antisaccade task, a sort of eyes-only video game where you have to stop yourself from looking at a suddenly appearing light. You view a screen on which the red crosshairs at the center occasionally disappear just as a light flickers elsewhere on the screen. Your instructions are to not look at the light and instead to look in the opposite direction. A sensor detects any eye movement. It's a tough assignment, since

took the test. Compared with adults, teens tended to make less use of brain regions that monitor performance, spot errors, plan, and stay focused—areas the adults seemed to bring online automatically. This let the adults use a variety of brain resources and better resist temptation, while the teens used those areas less often and more readily gave in to the impulse to look at the flickering light—just as they're more likely to look away from the road to read a text message.

If offered an extra reward, however, teens showed they could push those executive regions to work harder, improving their scores. And by age 20, their brains respond to this task much as the adults' do. Luna suspects the improvement comes as richer networks and faster connections make the executive region more effective.

These studies help explain why teens behave with such vexing inconsistency: beguiling at breakfast, disgusting at dinner; masterful on Monday, sleepwalking on Saturday. Along with lacking experience generally, they're still learning to use their brain's new networks. Stress, fatigue, or challenges can cause a misfire. Abigail Baird, a Vassar psychologist who studies teens, calls this neural gawkiness—an equivalent to the physical awkwardness teens sometimes display while mastering their growing bodies.

The slow and uneven developmental arc revealed by these imaging studies offers an alluringly pitiful explanation for why teens may do stupid things like drive at 113 miles an hour, aggravate their ancestry, and get people (or get gotten) with child: They act that way because their brains aren't done! You can see it right there in the scans!

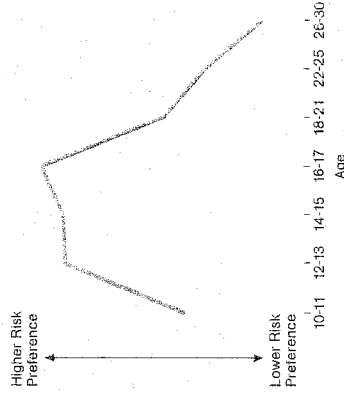
This view, as titles from the explosion of scientific papers and popular articles about the "teen brain" put it, presents adolescents as "works in progress" whose "immature brains" lead some to question whether they are in a state "akin to mental retardation."

**Troublesome traits like idiocy and haste don't really characterize adolescence. They're just what we notice most because they annoy us or put our children in danger.**

Flickering lights naturally draw our attention. To succeed, you must override both a normal impulse to attend to new information and curiosity about something forbidden. Brain geeks call this response inhibition.

Ten-year-olds stink at it, failing about 45 percent of the time. Teens do much better. In fact, by age 15 they can score as well as adults if they're motivated, resisting temptation about 70 to 80 percent of the time. What Luna found most interesting, however, was not those scores. It was the brain scans she took while people

## TEENY BUSINESS



Teens may understand that risky behaviors such as smoking and unprotected sex carry consequences. Yet adolescents tend to give more weight to the pleasures than to the costs.

Let's start with the teen's love of the thrill. We all like new and exciting things, but we never value them more highly than we do during adolescence. Here we hit a high in what behavioral scientists call sensation seeking: the hunt for the neural buzz, the jolt of the unusual or unexpected.

Seeking sensation isn't necessarily impulsive. You might plan a sensation-seeking experience—a skydive or a fast drive—quite deliberately, as my son did. Impulsivity generally drops throughout life, starting at about age 10, but this love of the thrill peaks at around age 15. And although sensation seeking can lead to dangerous behaviors, it can also generate positive ones: The urge to meet more people, for instance, can create a wider circle of friends, which generally makes us healthier, happier, safer, and more successful.

This upside probably explains why an openness to the new, though it can sometimes kill the cat, remains a highlight of adolescent development. A love of novelty leads directly to useful experience. More broadly, the hunt for sensation provides the inspiration needed to "get you out of the house" and into new terrain, as Jay Giedd, a pioneering researcher in teen brain development at NIH, puts it.

The story you're reading right now, however, tells a different scientific tale about the teen brain. Over the past five years or so, even as the work-in-progress story spread into our culture, the discipline of adolescent brain studies learned to do some more-complex thinking of its own. A few researchers began to view recent brain and genetic findings in a brighter, more flattering light, one distinctly colored by evolutionary theory. The resulting account of the adolescent brain—call it the adaptive-adolescent story—casts the teen less as a rough draft than as an exquisitely sensitive, highly adaptable creature wired almost perfectly for the job of moving from the safety of home into the complicated world outside.

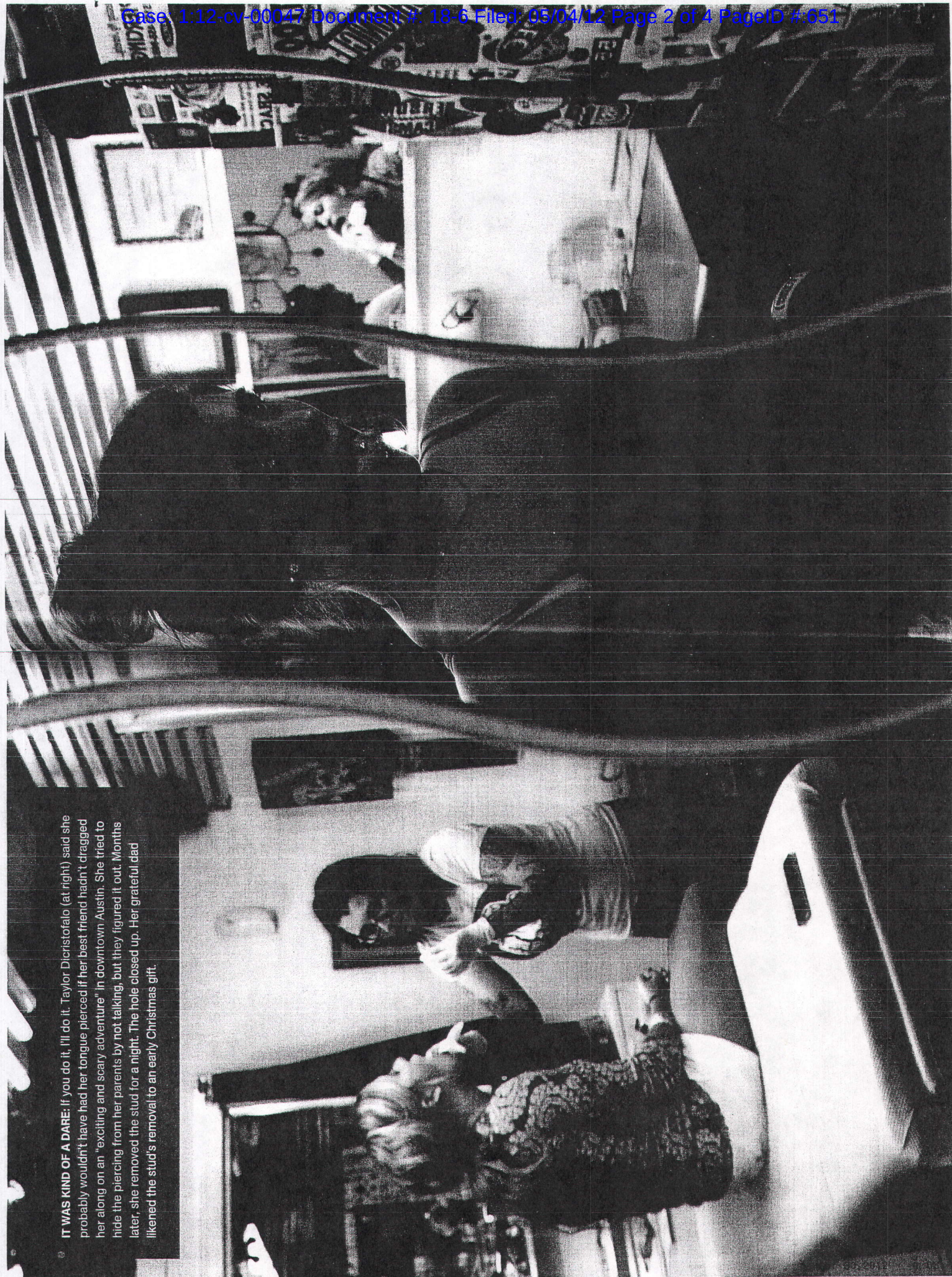
This view will likely sit better with teens. More important, it sits better with biology's most fundamental principle, that of natural selection. Selection is hell on dysfunctional traits. If adolescence is essentially a collection of them—angst, idiocy, and haste; impulsiveness, selfishness, and reckless bumbling—then how did those traits survive selection? They couldn't—not if they were the period's most fundamental or consequential features.

The answer is that those troublesome traits don't really characterize adolescence; they're just what we notice most because they annoy us or put our children in danger. As B. J. Casey, a neuroscientist at Weill Cornell Medical College who has spent nearly a decade applying brain and genetic studies to our understanding of adolescence, puts it, "We're so used to seeing adolescence as a problem. But the more we learn about what really makes this period unique, the more adolescence starts to seem like a highly functional, even adaptive period. It's exactly what you'd need to do the things you have to do then."

**TO SEE PAST** the distracting, dopey teenager and glimpse the adaptive adolescent within, we should look not at specific, sometimes startling, behaviors, such as skateboarding down stairways or dating fast company, but at the broader traits that underlie those acts.



**IT WAS KIND OF A DARE:** If you do it, I'll do it. Taylor Dieristofalo (at right) said she probably wouldn't have had her tongue pierced if her best friend hadn't dragged her along on an "exciting and scary adventure" in downtown Austin. She tried to hide the piercing from her parents by not talking, but they figured it out. Months later, she removed the stud for a night. The hole closed up. Her grateful dad likened the stud's removal to an early Christmas gift.







**NO ELBOWS, NO KNEES.** Their "fight club" had rules. At least one Friday a month, boys gathered after school in the backyard of Bryan Campbell (at far left) to wrestle and box. Campbell's mother gave her OK as long as they kept it safe; a bloody nose was the worst injury suffered. The boys often used phones to film their contests, then posted the videos to a private group on Facebook, where more friends could admire their prowess. The rush of a headlock, a bond between friends—their fights delivered both excitement and social rewards.



Also peaking during adolescence (and perhaps aggravating the ancentry the most) is risk-taking. We court risk more avidly as teens than at any other time. This shows reliably in the lab, where teens take more chances in controlled experiments involving everything from card games to simulated driving. And it shows in real life, where the period from roughly 15 to 25 brings peaks in all sorts of risky ventures and ugly outcomes. This age group dies of accidents of almost every sort (other than work accidents) at high rates. Most long-term drug or alcohol abuse starts during adolescence, and even people who later drink responsibly often drink too much as teens. Especially in cultures where teenage driving is common, this takes a gory toll: In the U.S., one in three teen deaths is from car crashes, many involving alcohol.

Are these kids just being stupid? That's the conventional explanation: They're not thinking, or by the work-in-progress model, their puny developing brains fail them.

Yet these explanations don't hold up. As

**In scientific terms, teenagers can be a pain in the ass. But they are quite possibly the most fully, crucially adaptive human beings around.**

Laurence Steinberg, a developmental psychologist specializing in adolescence at Temple University, points out, even 14- to 17-year-olds—the biggest risktakers—use the same basic cognitive strategies that adults do, and they usually reason their way through problems just as well as adults. Contrary to popular belief, they also fully recognize they're mortal. And, like adults, says Steinberg, "teens actually overestimate risk." So if teens think as well as adults do and recognize risk just as well, why do they take more chances? Here, as elsewhere, the problem lies less in what teens lack compared with adults than in

what they have more of. Teens take more risks not because they don't understand the dangers but because they weigh risk versus reward differently (see chart, page 49): In situations where risk can get them something they want, they value the reward more heavily than adults do.

A video game Steinberg uses draws this out nicely. In the game, you try to drive across town in as little time as possible. Along the way you encounter several traffic lights. As in real life, the traffic lights sometimes turn from green to yellow as you approach them, forcing a quick go-or-stop decision. You save time—and score more points—if you drive through before the light turns red. But if you try to drive through the red and don't beat it, you lose even more time than you would have if you had stopped for it. Thus the game rewards you for taking a certain amount of risk but punishes you for taking too much.

When teens drive the course alone, in what Steinberg calls the emotionally "cool" situation of an empty room, they take risks at about the same

rates that adults do. Add stakes that the teen cares about, however, and the situation changes. In this case Steinberg added friends:

When he brought a teen's friends into the room to watch, the teen would take twice as many risks, trying to gun it through lights he'd stopped for before. The adults, meanwhile, drove no differently with a friend watching.

To Steinberg, this shows clearly that risk-taking rises not from puny thinking but from a higher regard for reward.

"They didn't take more chances because they suddenly downgraded the risk," says Steinberg. "They did so because they gave more weight to the payoff."

Researchers such as Steinberg and Casey believe this risk-friendly weighing of cost versus reward has been selected for because, over the course of human evolution, the willingness to take risks during this period of life has granted an adaptive edge. Succeeding often requires

moving out of the home and into less secure situations. "The more you seek novelty and take risks," says Baird, "the better you do." This responsiveness to reward thus works like the desire for new sensation: It gets you out of the house and into new turf.

As Steinberg's driving game suggests, teens respond strongly to social rewards. Physiology and evolutionary theory alike offer explanations for this tendency. Physiologically, adolescence brings a peak in the brain's sensitivity to dopamine, a neurotransmitter that appears to prime and fire reward circuits and aids in learning patterns and making decisions. This helps explain the teen's quickness of learning and extraordinary receptivity to reward—and his keen, sometimes melodramatic reaction to success as well as defeat.

The teen brain is similarly attuned to oxytocin, another neural hormone, which (among other things) makes social connections in particular more rewarding. The neural networks and dynamics associated with general reward and social interactions overlap heavily. Engage one, and you often engage the other. Engage them during adolescence, and you light a fire.

This helps explain another trait that marks adolescence: Teens prefer the company of those their own age more than ever before or after. At one level, this passion for same-age peers merely expresses in the social realm the teen's general attraction to novelty: Teens offer teens far more novelty than familiar old family does.

Yet teens gravitate toward peers for another, more powerful reason: to invest in the future rather than the past. We enter a world made by our parents. But we will live most of our lives, and prosper (or not) in a world run and remade by our peers. Knowing, understanding, and building relationships with them bears critically on success. Socially savvy rats or monkeys, for instance, generally get the best nesting areas or territories, the most food and water, more allies, and more sex with better and fitter mates. And no species is more intricately and deeply social than humans are.

This supremely human characteristic makes

peer relations not a sideshow but the main show. Some brain-scan studies, in fact, suggest that our brains react to peer exclusion much as they respond to threats to physical health or food supply. At a neural level, in other words, we perceive social rejection as a threat to existence. Knowing this might make it easier to abide the hysteria of a 13-year-old deceived by a friend or the gloom of a 15-year-old not invited to a party. These people! we lament. They react to social ups and downs as if their fates depended upon them! They're right. They do.

**EXCITEMENT, NOVELTY, RISK**, the company of peers. These traits may seem to add up to nothing more than doing foolish new stuff with friends. Look deeper, however, and you see that these traits that define adolescence make us more adaptive, both as individuals and as a species. That's doubtless why these traits, broadly defined, seem to show themselves in virtually all human cultures, modern or tribal. They may concentrate and express themselves more starkly in modern Western cultures, in which teens spend so much time with each other. But anthropologists have found that virtually all the world's cultures recognize adolescence as a distinct period in which adolescents prefer novelty, excitement, and peers. This near-universal recognition sinks the notion that it's a cultural construct.

Culture clearly shapes adolescence. It influences its expression and possibly its length. It can magnify its manifestations. Yet culture does not create adolescence. The period's uniqueness rises from genes and developmental processes that have been selected for over thousands of generations because they play an amplified role during this key transitional period: producing a creature optimally primed to leave a safe home and move into unfamiliar territory.

The move outward from home is the most difficult thing that humans do, as well as the most critical—not just for individuals but for a species that has shown an unmatched ability to master challenging new environments. In scientific terms, teenagers can be a pain in the ass. But they are quite possibly the most fully,